Nonautoclave Curing of Composite Flight Structures

Jeffrey L. Finckenor/ED52
205–544–7041

The high specific strength and stiffness of fiber composites make them excellent choices for use in the aerospace industry. Typically, composite parts are cured under high temperature and pressure in an autoclave, but, because the parts are so large, they often require very expensive autoclaves. Significant cost savings could come from using oven cures instead of autoclave cures. If the variations due to different layup techniques and part thicknesses are quantified, then both part weight and cost could be optimized.

This research project has two phases, with four objectives each. All samples are being made in the Productivity Enhancement Complex in Building 4707. Testing will take place in Building 4619.

Phase I: (1) quantify effects of cure, layup, and thickness; (2) ensure predictability of oven- and autoclave-cured composite honeycomb structures; (3) evaluate bonded composite structural joints; and (4) evaluate embedded fiber-optic health monitoring.

Objective 1: Cure, layup, and thickness. Autoclaves are used to provide pressure to compact plies of the laminate together so strong bonds are formed. Using an oven, or doing a hand layup, provides less compaction. This experiment determines if there is a significant loss in material properties due to methods that provide less compaction.

The effects and interaction of the factors will be studied with a 2^3 factorial experiment with two replicates. Compression and shear tests will provide material properties. The design factors and their levels are: (1) cure: oven and autoclave, (2) layup: hand- and tape-laying machine, and (3) thickness: 8- and 52-ply. The tests will be done on three material systems: AS4/3501–6, IM7/8551–7, and IM7/F655 (Bismaleimide). An additional material, IM7/F584, may also be studied.

An additional set of tests with more replicates will be conducted on AS4/3501–6 to compare only the oven and autoclave properties. Results will include all nine in-plane material properties and strengths.

Objective 2: Oven and autoclave honeycomb predictability. Using the same three materials as for Objective 1, three point-bend tests and column-buckling tests will be performed and compared with predicted failures.

Objective 3: Bonded joints. Bonded joints are a simple and economical way of joining composite structures, but adhesive bonds are very difficult to analyze reliably. These tests will provide data for future designs requiring bonded joints.

Aluminum and composite double-lap splices will be used to bond together composite plates and composite honeycomb samples. Aluminum channels will also be bonded and co-cured on the inside of a composite honeycomb, then bolted together to simulate a thrusting-type payload shroud separation joint.

Objective 4: Embedded sensors. Vehicle health monitoring is becoming more important to the aerospace industry. One method uses embedded fiber-optic strain sensors in composite structures. This experiment will provide data for using sensors on a flight-like structure.

The panel-splice tests will incorporate a fiber-optic sensor in the composite splices. The strain-sensors are Fabry-Perot differential strain-measuring devices. For comparison, a uniaxial strain gauge and a coating of photostress material will be employed on the same parts.

Phase II: (1) study predictability of post first-ply failure behavior; (2) evaluate single-lap bonded and bolted joints; (3) develop a time-load-strain relationship; and (4) apply information from phase I to a large-scale cylinder.

Objective 1: Post first-ply failure. Many current failure theories used on composites are very weak in theory, but are still commonly used for lack of a better analysis. To study failure, bend tests will be conducted on 12- and 40-ply IM7/8552 layups and optimized by classical lamination theory and the Tsai-Hill failure criterion for the maximum number of ply failures before ultimate failure. The actual and predicted load-deflection curves will be compared.

Objective 2: Single-lap joints. Single-lap joints are structurally much less efficient than double-lap joints, but design constraints may occasionally force a single-lap joint. Composites have more potential problems with this than metals because of the low material properties through the thickness. Tension samples of IM7/8552 will be tested using single-bolted, double-bolted, and bonded single-lap joints.

Objective 3: Time-load-strain. The matrix of many fiber composites is a viscoelastic material—meaning the strain is a function of load and time. While this effect is largely mitigated by the fibers in the 0-degree direction, the 90-degree direction can be strongly affected.

Tape-layed AS4/3501–6, 0-, 90-, and ±45-degree (shear) samples will be loaded at 30, 60, and 90 percent of their ultimate load, and the strain will be recorded over time. This information will allow the development of a time-load relationship for material stiffnesses.

Objective 4: Large cylinder. To apply the information learned from the other tests, a cylinder (3 feet in diameter and 6 feet long) will be fiber-placed using IM7/8552. It will be cut in half, bonded together, and then tested to failure. This cylinder will weigh 50 pounds and be able to support 900,000 pounds.

Conclusion. These tests will provide a significant experience data base for the development of future launch vehicles at MSFC.

The study of oven-cured parts will quantify the effect on material properties due to less-expensive manufacturing methods, which could reduce the cost of manufacturing many composite parts.

Sponsor: Center Director’s Discretionary Fund

■■■■■